PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference P368B-PCT	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
International application No. PCT/US99/20220	International filing date *(day/month/year)* 02 SEPTEMBER 1999	(Earliest) Priority Date *(day/month/year)* 03 SEPTEMBER 1998
Applicant THE REGENTS OF THE UNIVERSITY OF CALIFORNIA		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

[X] It is also accompanied by a copy of each prior art document cited in this report.

1. [ ] **Certain claims were found unsearchable** (See Box I).

2. [ ] **Unity of invention is lacking** (See Box II).

3. [ ] The international application contains disclosure of a **nucleotide and/or amino acid sequence listing** and the international search was carried out on the basis of the sequence listing
   - [ ] filed with the international application.
   - [ ] furnished by the applicant separately from the international application,
     - [ ] but not accompanied by a statement to the effect that it did not include matter going beyond the disclosure in the international application as filed.
   - [ ] transcribed by this Authority.

4. With regard to the **title**,
   - [X] the text is approved as submitted by the applicant.
   - [ ] the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   - [ ] the text is approved as submitted by the applicant.
   - [X] the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is:

   Figure No. 1
   - [ ] as suggested by the applicant.
   - [ ] because the applicant failed to suggest a figure.
   - [X] because this figure better characterizes the invention.
   - [ ] None of the figures.

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

The technical features mentioned in the abstract do not include a reference sign between parentheses (PCT Rule 8.1(d)).

NEW ABSTRACT

A drag reducing fluid pumped (22) through a heat exchanger (12).

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/20220

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :F24H 3/00; C10M 105/08; C09K 5/00
US CL :165/47; 252/34, 71
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 165/47; 252/34, 71

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,143,625 A (YOUNG et al) 01 September 1992, see entire document.	1-27
X	US 4,534,875 A (ROSE) 13 August 1985, see entire document.	1-27

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 25 OCTOBER 1999	Date of mailing of the international search report 18 NOV 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer J. Hurley for CHRISTOPHER ATKINSON Telephone No. (703) 308-2603

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To: DANIEL L. DAWES
MYERS, DAWES & ANDRAS LLP
650 TOWN CENTER DRIVE
SUITE 650
COSTA MESA, CA 92626

PCT

NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of Mailing *(day/month/year)*	30 AUG 2000
Applicant's or agent's file reference: P368B-PCT	**IMPORTANT NOTIFICATION**

International application No.	International filing date *(day/month/year)*	Priority Date *(day/month/year)*
PCT/US99/20220	02 SEPTEMBER 1999	03 SEPTEMBER 1998

Applicant

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

   The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

   Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

   For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Stacia Cadmus for CHRISTOPHER ATKINSON Telephone No. (703) 308-2603

Form PCT/IPEA/416 (July 1992)★

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P368B-PCT	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/US99/20220	International filing date (day/month/year) 02 SEPTEMBER 1999	Priority date *(day/month/year)* 03 SEPTEMBER 1998

International Patent Classification (IPC) or national classification and IPC
IPC(7): F24H 3/00; C10M 105/08; C09K 5/00 and US Cl.: 165/47; 252/34, 71

Applicant
THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 3 sheets.

   ☐ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority. (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 0 sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of report with regard to novelty, inventive step or industrial applicability
   IV ☐ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   VI ☐ Certain documents cited
   VII ☐ Certain defects in the international application
   VIII ☐ Certain observations on the international application

Date of submission of the demand 30 MARCH 2000	Date of completion of this report 31 JULY 2000
Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Stacia Cadmus CHRISTOPHER ATKINSON for Telephone No. (703) 308-2603

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/US99/20220

I. Basis of the report

1. With regard to the elements of the international application:*

[X] the international application as originally filed

[X] the description:
pages 1-23, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ____

[X] the claims:
pages 24-33, as originally filed
pages NONE, as amended (together with any statement) under Article 19
pages NONE, filed with the demand
pages NONE, filed with the letter of ____

[X] the drawings:
pages 1-2, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ____

[X] the sequence listing part of the description:
pages NONE, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of ____

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language ____ which is:

[ ] the language of a translation furnished for the purposes of international search (under Rule 23.1(b)).

[ ] the language of publication of the international application (under Rule 48.3(b)).

[ ] the language of the translation furnished for the purposes of international preliminary examination (under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

[ ] contained in the international application in printed form.

[ ] filed together with the international application in computer readable form.

[ ] furnished subsequently to this Authority in written form.

[ ] furnished subsequently to this Authority in computer readable form.

[ ] The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

[ ] The statement that the information recorded in computer readable form is identical to the writen sequence listing has been furnished.

4. [X] The amendments have resulted in the cancellation of:

[X] the description, pages NONE
[X] the claims, Nos. NONE
[X] the drawings, sheets/~~fig~~ NONE

5. [ ] This report has been drawn as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

* *Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

***Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. statement

Novelty (N)	Claims	1-27	YES
	Claims	NONE	NO
Inventive Step (IS)	Claims	1-27	YES
	Claims	NONE	NO
Industrial Applicability (IA)	Claims	1-27	YES
	Claims	NONE	NO

2. citations and explanations (Rule 70.7)

Claims 1-27 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a drag reducing fluid and a heat exchanger having fluid degradation properties and the fluid having fluid recovery properties.

-------------------- NEW CITATIONS --------------------

NONE

HOME COPY

PCT

REQUEST

The undersigned requests that the present international application be processed according to the Patent Cooperation Treaty.

For receiving Office use only

International Application No. PCT/US 99 / 20220

(02.09.99)

International Filing Date 02 SEP 1999

Name of receiving Office and "PCT International Application"

Applicant's or agent's file reference *(if desired) (12 characters maximum)* P368b-PCT

Box No. I TITLE OF INVENTION
Methods to Control Heat Transfer In Fluids Containing Drag-Reducing Additives

Box No. II APPLICANT

Name and address: *(Family name followed by given name; for a legal entity, full official The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

The Regents of the University of California
a California Corporation
1111 Franklin Street, 12th Floor
Oakland, California 94607
United States of America

☐ This person is also inventor.

Telephone No.
(510) 587-6000

Facsimile No.
(510) 587-6090

Teleprinter No.

State *(that is, country)* of nationality: ~~U.S.~~ US

State *(that is, country)* of residence: ~~U.S.~~ US

This person is applicant for the purposes of: ☐ all designated States ☒ all designated States except the United States of America ☐ the United States of America only ☐ the States indicated in the Supplemental Box

Box No. III FURTHER APPLICANT(S) AND/OR (FURTHER) INVENTOR(S)

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

GASLJEVIC, Kazimir
2519 Chapala
Santa Barbara, California 93105
United States of America

This person is:

☐ applicant only

☒ applicant and inventor

☒ inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Croatia

State *(that is, country)* of residence: ~~U.S.~~ US

This person is applicant for the purposes of: ☐ all designated States ☐ all designated States except the United States of America ☒ the United States of America only ☐ the States indicated in the Supplemental Box

☒ Further applicants and/or (further) inventors are indicated on a continuation sheet.

Box No. IV AGENT OR COMMON REPRESENTATIVE; OR ADDRESS FOR CORRESPONDENCE

The person identified below is hereby/has been appointed to act on behalf of the applicant(s) before the competent International Authorities as: ☒ agent ☐ common representative

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)*

DAWES, Daniel L.
MYERS, DAWES & ANDRAS LLP
650 Town Center Drive, Suite 650
Costa Mesa, California 92626
United States of America

Telephone No.
(714) 444-1199

Facsimile No.
(714) 444-1198

Teleprinter No.

☐ **Address for correspondence:** Mark this check-box where no agent or common representative is/has been appointed and the space above is used instead to indicate a special address to which correspondence should be sent.

▲ADDED BY RO/US

▲RO/US

Sheet No. ...2... T/US 99 / 20220

Continuation of Box No. II FURTHER APPLICANTS AND/OR (FURTHER) INVENTOR(S)

If none of the following sub-boxes is used, this sheet is not to be included in the request.

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

MATTHYS, Eric F.
1263 San Antonio Creek Road
Santa Barbara, California 93111
United States of America

This person is:

- [ ] applicant only
- [x] applicant and inventor
- [x] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality: Belgium

State *(that is, country)* of residence: ~~U.S.~~ US

This person is applicant for the purposes of: [ ] all designated States [ ] all designated States except the United States of America [x] the United States of America only [ ] the States indicated in the Supplemental Box

▲ DELETED BY RO/US

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: [ ] all designated States [ ] all designated States except the United States of America [ ] the United States of America only [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

▲RO/US

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: [ ] all designated States [ ] all designated States except the United States of America [ ] the United States of America only [ ] the States indicated in the Supplemental Box

Name and address: *(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country. The country of the address indicated in this Box is the applicant's State (that is, country) of residence if no State of residence is indicated below.)*

This person is:

- [ ] applicant only
- [ ] applicant and inventor
- [ ] inventor only *(If this check-box is marked, do not fill in below.)*

State *(that is, country)* of nationality:

State *(that is, country)* of residence:

This person is applicant for the purposes of: [ ] all designated States [ ] all designated States except the United States of America [ ] the United States of America only [ ] the States indicated in the Supplemental Box

[ ] Further applicants and/or (further) inventors are indicated on another continuation sheet.

Box No.V DESIGNATION OF STATES

The following designations are hereby made under Rule 4.9(a) *(mark the applicable check-boxes; at least one must be marked)*:

Regional Patent

☒ **AP** **ARIPO Patent:** **GH** Ghana, **GM** Gambia, **KE** Kenya, **LS** Lesotho, **MW** Malawi, **SD** Sudan, **SZ** Swaziland, **UG** Uganda, **ZW** Zimbabwe, and any other State which is a Contracting State of the Harare Protocol and of the PCT

☒ **EA** **Eurasian Patent:** **AM** Armenia, **AZ** Azerbaijan, **BY** Belarus, **KG** Kyrgyzstan, **KZ** Kazakhstan, **MD** Republic of Moldova, **RU** Russian Federation, **TJ** Tajikistan, **TM** Turkmenistan, and any other State which is a Contracting State of the Eurasian Patent Convention and of the PCT

☒ **EP** **European Patent:** **AT** Austria, **BE** Belgium, **CH and LI** Switzerland and Liechtenstein, **CY** Cyprus, **DE** Germany, **DK** Denmark, **ES** Spain, **FI** Finland, **FR** France, **GB** United Kingdom, **GR** Greece, **IE** Ireland, **IT** Italy, **LU** Luxembourg, **MC** Monaco, **NL** Netherlands, **PT** Portugal, **SE** Sweden, and any other State which is a Contracting State of the European Patent Convention and of the PCT

☒ **OA** **OAPI Patent:** **BF** Burkina Faso, **BJ** Benin, **CF** Central African Republic, **CG** Congo, **CI** Cote d'Ivoire, **CM** Cameroon, **GA** Gabon, **GN** Guinea, **GW** Guinea-Bissau, **ML** Mali, **MR** Mauritania, **NE** Niger, **SN** Senegal, **TD** Chad, **TG** Togo, and any other State which is a member State of OAPI and a Contracting State of the PCT *(if other kind of protection or treatment desired, specify on dotted line)* ....

National Patent *(if other kind of protection or treatment desired, specify on dotted line)*:

☒ **AL** Albania ....
☒ **AM** Armenia ....
☒ **AT** Austria ....
☒ **AU** Australia ....
☒ **AZ** Azerbaijan
☒ **BA** Bosnia and Herzegovina ....
☒ **BB** Barbados
☒ **BG** Bulgaria ....
☒ **BR** Brazil ....
☒ **BY** Belarus ....
☒ **CA** Canada ....
☒ **CH and LI** Switzerland and Liechtenstein
☒ **CN** China ....
☒ **CU** Cuba ....
☒ **CZ** Czech Republic ....
☒ **DE** Germany ....
☒ **DK** Denmark ....
☒ **EE** Estonia ....
☒ **ES** Spain ....
☒ **FI** Finland ....
☒ **GB** United Kingdom
☒ **GD** Grenada
☒ **GE** Georgia ....
☒ **GH** Ghana ....
☒ **GM** Gambia
☒ **HR** Croatia ....
☒ **HU** Hungary ....
☒ **ID** Indonesia
☒ **IL** Israel ....
☐ **IN** India ....
☒ **IS** Iceland
☒ **JP** Japan ....
☒ **KE** Kenya ....
☒ **KG** Kyrgyzstan ....
☒ **KP** Democratic People's Republic of Korea ....
☒ **KR** Republic of Korea ....
☒ **KZ** Kazakhstan ....
☒ **LC** Saint Lucia
☒ **LK** Sri Lanka
☒ **LR** Liberia
☒ **LS** Lesotho ....
☒ **LT** Lithuania
☒ **LU** Luxembourg
☒ **LV** Latvia
☒ **MD** Republic of Moldova ....
☒ **MG** Madagascar ....
☒ **MK** The former Yugoslav Republic of Macedonia ....
☒ **MN** Mongolia
☒ **MW** Malawi ....
☒ **MX** Mexico ....
☒ **NO** Norway
☒ **NZ** New Zealand ....
☒ **PL** Poland ....
☒ **PT** Portugal ....
☒ **RO** Romania
☒ **RU** Russian Federation ....
☒ **SD** Sudan
☒ **SE** Sweden
☒ **SG** Singapore
☒ **SI** Slovenia ....
☒ **SK** Slovakia ....
☒ **SL** Sierra Leone
☒ **TJ** Tajikistan ....
☒ **TM** Turkmenistan ....
☒ **TR** Turkey ....
☒ **TT** Trinidad and Tobago ....
☒ **UA** Ukraine ....
☒ **UG** Uganda ....
☒ **US** United States of America ....
☒ **UZ** Uzbekistan ....
☒ **VN** Viet Nam ....
☒ **YU** Yugoslavia ....
☒ **ZW** Zimbabwe ....

Check-boxes reserved for designating States (for the purposes of a national patent) which have become party to the PCT after issuance of this sheet:

☐ ....
☐ ....
☐ ....

Precautionary Designation Statement: In addition to the designations made above, the applicant also makes under Rule 4.9(b) all other designations which would be permitted under the PCT except any designation(s) indicated in the Supplemental Box as being excluded from the scope of this statement. The applicant declares that those additional designations are subject to confirmation and that any designation which is not confirmed before the expiration of 15 months from the priority date is to be regarded as withdrawn by the applicant at the expiration of that time limit. *(Confirmation of a designation consists of the filing of a notice specifying that designation and the payment of the designation and confirmation fees. Confirmation must reach the receiving Office within the 15-month time limit.)*

Sheet No. ....4..   PCT/US 99/20220

Box No. VI PRIORITY CLAIM ☐ Further priority claims are indicated in the Supplemental Box.

Filing date of earlier application (day/month/year)	Number of earlier application	Where earlier application is: national application: country	regional application:* regional Office	international application: receiving Office
item (1) 03 September 1998 (03.09.98)	09/148,029	~~U.S.~~ US		
item (2)				
item (3)				

☒ The receiving Office is requested to prepare and transmit to the International Bureau a certified copy of the earlier application(s) *(only if the earlier application was filed with the Office which for the purposes of the present international application is the receiving Office)* identified above as item(s): (1)

** Where the earlier application is an ARIPO application, it is mandatory to indicate in the Supplemental Box at least one country party to the Paris Convention for the Protection of Industrial Property for which that earlier application was filed (Rule 4.10(b)(ii)). See Supplemental Box.*

Box No. VII INTERNATIONAL SEARCHING AUTHORITY

Choice of International Searching Authority (ISA) *(if two or more International Searching Authorities are competent to carry out the international search, indicate the Authority chosen; the two-letter code may be used):*

ISA/US

Request to use results of earlier search; reference to that search *(if an earlier search has been carried out by or requested from the International Searching Authority):*

Date *(day/month/year)* Number Country (or regional Office)

Box No. VIII CHECK LIST: LANGUAGE OF FILING

This international application contains the following **number of sheets:**

request	:	4
description (excluding sequence listing part)	:	23
claims	:	10
abstract	:	1
drawings	:	2
sequence listing part of description	:	
Total number of sheets	:	40

This international application is **accompanied** by the item(s) marked below:

1. ☒ fee calculation sheet
2. ☒ separate signed power of attorney
3. ☐ copy of general power of attorney; reference number, if any:
4. ☐ statement explaining lack of signature
5. ☐ priority document(s) identified in Box No. VI as items(s):
6. ☐ translation of international application into (language):
7. ☐ separate indications concerning deposited microorganism or other biological material
8. ☐ nucleotide and/or amino acid sequence listing in computer readable form
9. ☒ other *(specify)*: Express Mail Certificate and Acknowledgement Postcard

Figure of the drawings which should accompany the abstract: 3

Language of filing of the international application: English

Box No. IX SIGNATURE OF APPLICANT OR AGENT

Next to each signature, indicate the name of the person signing and the capacity in which the person signs (if such capacity is not obvious from reading the request).

Daniel L. Dawes

Daniel L. Dawes, Attorney of Record

▲RO/US

For receiving Office use only (02.09.99)

1. Date of actual receipt of the purported international application: 524 Rec'd PCT/PTO 02 SEP 1999	2. Drawings: ☐ received: ☐ not received:
3. Corrected date of actual receipt due to later but timely received papers or drawings completing the purported international application:	
4. Date of timely receipt of the required corrections under PCT Article 11(2):	
5. International Searching Authority (if two or more are competent): ISA/US	6. ☐ Transmittal of search copy delayed until search fee is paid

For International Bureau use only

Date of receipt of the record copy by the International Bureau:

UC CASE NO. 96-010-3

PCT

PCT/US 99/20220

POWER OF ATTORNEY

(for an international application filed under the Patent Cooperation Treaty)

(PCT Rule 90.4)

The undersigned applicant(s) *(Names should be indicated as they appear in the request)*:

The Regents of the University of California
1111 Franklin Street, 12th Floor
Oakland, California 94607
United States of America

hereby appoints (appoint) the following person as: ☒ agent ☐ common representative

Name and address
(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

DAWES, Daniel L.
MYERS, DAWES & ANDRAS LLP
650 Town Center Drive, Suite 650
Costa Mesa, California 92626
United States of America

to represent the undersigned before

☒ all the competent International Authorities
☐ the International Searching Authority only
☐ the International Preliminary Examining Authority only

in connection with the international application identified below:

Title of the invention: Methods to Control Heat Transfer in Fluids Containing Drag-Reducing Additives

Applicant's or agent's file reference: P368b PCT

International application number (if already available):

filed with the following Office US as receiving Office
and to make or receive payments on behalf of the undersigned.

Signature of the applicant(s) *(where there are several applicants, each of them must sign; next to each signature, indicate the name of the person signing and the capacity in which the person signs, if such capacity is not obvious from reading the request or this power):*

Linda S. Stevenson

Linda S. Stevenson, Principal Prosecution Analyst, Office of Technology Transfer
This person is authorized to sign on behalf of the above-identified applicant.

Date: ______________________

T/US 99/20220

PCT

POWER OF ATTORNEY

(for an international application filed under the Patent Cooperation Treaty)

(PCT Rule 90.4)

The undersigned applicant(s) *(Names should be indicated as they appear in the request)*:

GASLJEVIC, Kazimir
2519 Chapala
Santa Barbara, California 93105
United States of America

hereby appoints (appoint) the following person as: ☒ agent ☐ common representative

Name and address
(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

DAWES, Daniel L.
MYERS, DAWES & ANDRAS LLp
650 Town Center Drive, Suite 650
Costa Mesa, California 92626
United States of America

to represent the undersigned before

☒ all the competent International Authorities
☐ the International Searching Authority only
☐ the International Preliminary Examining Authority only

in connection with the international application identified below:

Title of the invention: Methods to Control Heat Transfer in Fluids Containing Drag-Reducing Additives

Applicant's or agent's file reference: P368b PCT

International application number (if already available):

filed with the following Office US as receiving Office
and to make or receive payments on behalf of the undersigned.

Signature of the applicant(s) *(where there are several applicants, each of them must sign; next to each signature, indicate the name of the person signing and the capacity in which the person signs, if such capacity is not obvious from reading the request or this power)*:

Kazimir Gasljevic

Date: August 31, 1999

PCT/US 99/20220

PCT

POWER OF ATTORNEY

(for an international application filed under the Patent Cooperation Treaty)

(PCT Rule 90.4)

The undersigned applicant(s) *(Names should be indicated as they appear in the request)*:

MATTHYS, Eric F.
1263 San Antonio Creek Road
Santa Barbara, California 93111
United States of America

hereby appoints (appoint) the following person as: ☒ agent ☐ common representative

Name and address
(Family name followed by given name; for a legal entity, full official designation. The address must include postal code and name of country.)

DAWES, Daniel L.
MYERS, DAWES & ANDRAS LLP
650 Town Center Drive, Suite 650
Costa Mesa, California 92626
United States of America

to represent the undersigned before
☒ all the competent International Authorities
☐ the International Searching Authority only
☐ the International Preliminary Examining Authority only

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Eric F. Matthys
Eric F. Matthys

Date: 8/31/99

This sheet is not part of and does not count as a sheet of the international application.

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FEE CALCULATION SHEET

Annex to the Request

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PCT/US 99/20220

International application No.

(02.09.99) 02 SEP 1999

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Applicant's or agent's file reference: P368b-PCT

Applicant
The Regents of the University of California

CALCULATION OF PRESCRIBED FEES

1. TRANSMITTAL FEE	240.00	T	240
2. SEARCH FEE	210.00	S	450

International search to be carried out by **U.S.**

(If two or more International Searching Authorities are competent in relation to the international application, indicate the name of the Authority which is chosen to carry out the international search.)

3. INTERNATIONAL FEE

Basic Fee

The international application contains **40** sheets.

first 30 sheets	455.00	b_1	455
10 remaining sheets x **$10.00** additional amount =	100.00	b_2	100
Add amounts entered at b_1 and b_2 and enter total at B	555.00	B	555

Designation Fees

The international application contains **all** designations.

11 number of designation fees payable *(maximum 10)* x **105.00** amount of designation fee =	1,155.00	D	1,050
Add amounts entered at B and D and enter total at I	1,710.00	I	1,605

(Applicants from certain States are entitled to a reduction of 75% of the international fee. Where the applicant is (or all applicants are) so entitled,

4. FEE FOR PRIORITY DOCUMENT *(if applicable)*		P	15
5. TOTAL FEES PAYABLE Add amounts entered at T, S, I and P, and enter total in the TOTAL box	2,160.00	TOTAL	2310

☐ The designation fees are not paid at this time.

MODE OF PAYMENT

- ☐ authorization to charge deposit account (see below)
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- ☐ postal money order
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01-1960	**26 August 1999**	Daniel L. Dawes
Deposit Account Number	Date *(day/month/year)*	Signature

METHODS TO CONTROL HEAT TRANSFER IN FLUIDS CONTAINING DRAG-REDUCING ADDITIVES

UC Case No. 96-010-3

Ref No. : P368b-PCT

Inventors : K. Gasljevic and E.F. Matthys

METHODS TO CONTROL HEAT TRANSFER IN FLUIDS CONTAINING DRAG-REDUCING ADDITIVES

Related Applications

The present application is a continuation-in-part application of application serial no. 09/148,029, filed Sept. 3, 1998 which in turn was related to provisional patent application, serial no. 60/057,924, filed on Sept. 4, 1997, both of which are incorporated herein by reference as if set forth in their entirety.

Background Of The Invention

1. *Field of the Invention*

This invention relates to the recovery of the heat transfer in heat exchangers in circulation loops in which drag-reducing surfactant solutions are used for reduction of pumping power expended to pump heat exchanging fluid through the hydronic system.

2. *Description of the Prior Art*

Drag-reducing additives can decrease friction in pipes with all else being equal. This reduced pipe wall friction does result in a decrease in the pumping power necessary to circulate a fluid in a piping system, or alternatively could result in greater flow rate or even in longer system reach than without additives.

A decrease in pumping power would save energy in many systems such as recirculating hydronic HVAC systems or other types where water or another fluid are used as thermal transport agent for cooling or heating.

Unfortunately, if the system includes heat exchangers, the heat transfer is also greatly decreased by the additives and the heat exchangers show reduced efficiency. In the case of a cooling system, for example, the chiller has to work with larger refrigerant temperature difference, and the energy savings in the pumps are countered by the additional chiller work, and the total energy savings may be reduced, eliminated, or there could even be a net increase in overall system energy *use*. A similar effect is seen in heating systems. By introducing a conventional heat transfer enhancement device it is possible to modify the flow and to increase heat transfer as in the case of water, but this is generally not a suitable solution because the losses due to the insert are too high in many cases.

Drag-reducing surfactant solutions have been used for reducing pumping power in circulation systems under turbulent flow conditions. The reduced heat transfer that inevitably accompanies drag reduction in any turbulent pipe flow was accepted as an undesirable by-effect in most applications or uses. Special types of heat exchangers, like plate heat exchangers, which make use of narrow passages instead of pipes, show smaller heat and drag reductions. In general, however, the application of drag-reducing additives in any circulation system that

includes heat transfer in most possible applications is inhibited by reduction of heat transfer efficiency in the heat exchangers.

What is needed is an apparatus and method whereby the use of any type of heat exchanger with drag-reducing surfactant additives can be realized without substantial or excessive reduction in heat transfer.

Brief Summary Of The Invention

Instead of modifying just the flow, it is possible to modify the fluid temporarily by a suitable fluid degrading device. This has to be done so as not to require too much flow work, but yet to still destroy the fluid structure for a suitable period of time sufficient to cover the residence time of the fluid in the heat exchanger. According to the invention it is possible to customize the fluid to achieve the desirable recovery time needed. This can then be used to control heat transfer. This may also be done in some cases done through a temperature jump.

According to the invention it is possible to find or develop a fluid that would have suitable characteristics so as to optimize the application of the invented method of heat transfer control by achieving the temperature independence of drag reducing, degradation and recovery characteristics of the drag reducing surfactant solution.

More particularly the invention is an improvement in a heat exchanger comprising a surfactant solution flowing through the heat exchanger which reduces fluid drag within the hydronic system.

The surfactant solution is characterized by a predetermined recovery time as defined by ability of the surfactant solution to rebuild molecular or micellar structures after disruption of the molecular or micellar structures. A degrading device creates a stress field in or before the heat exchanger to break or disrupt the molecular or micellar structures in the surfactant solution by high local shear stresses so that heat transfer rate of the surfactant solution is increased, by elimination of drag and heat transfer reducing ability of the degraded surfactant solution for a predetermined distance downstream from the degrading device during which recovery time the molecular or micellar structures are being rebuilt. The term "solution" is used in the specification and claims to encompass not only a solute in a solvent, but also mixtures of components and colloidal suspensions of a colloid.

The invention is also defined as a method of heat exchange comprising the steps of providing a surfactant solution as a heat exchanging fluid in a heat exchanger, which surfactant solution reduces fluid drag within the heat exchanger disposed in the heat exchanger. The surfactant solution is characterized by a predetermined recovery time as defined by ability of the surfactant solution to rebuild molecular or micellar structures after disruption of the molecular or micellar structures. The flow in the heat exchanger is disturbed

to break or disrupt the molecular or micellar structures in the surfactant solution by high local shear stresses so that heat transfer rate of the surfactant solution is increased by elimination of drag and heat transfer reducing ability of the degraded surfactant solution for a predetermined distance downstream from the disturbance during the recovery time, during which the molecular or micellar structures are being rebuilt.

The invention is still further defined as a method of heat transfer recovery in turbulent flow of drag reducing surfactant solutions comprising the steps of providing a degrading device which degrades the fluid with minimum pressure drop, creating temporary degradation of a circulating fluid, and conditioning of the drag reducing fluid properties relevant for degradation and recovery.

The invention is also the fluid itself which has optimized properties of stress resistance and recovery comprising a thermal transport fluid, such as water, and a surfactant additive capable of withstanding stress in all pipes and fittings of a circulation system and providing asymptotic drag reduction in the pipelines of the circulation system.

In a heat exchanger the fluid is degraded by a degrading device. The drag and heat transfer reductions are temporarily substantially eliminated. The fluid remaining substantially degraded during its residence in the heat exchanger after which recovery occurs quickly after the fluid exits from heat exchanger.

In one embodiment the fluid and surfactant in combination are characterized by a drag reduction recovery having a long dead time when the

drag-reduction has been essentially eliminated and a subsequent fast recovery to a substantially undegraded drag reduction level.

The invention is still further defined as a fluid having optimized properties of degradation and recovery comprising a thermal transport fluid, such as water, and a surfactant additive having, when added to thermal transport fluid, a substantial independence of recovery and degradation properties as a function of temperature. The surfactant additive comprises two or more types of surfactants with opposing effects of degradation and recovery parameters as a function of temperature. The additive may comprise a cationic surfactant and a nonionic surfactant, or any other combination of surfactants now known or later devised, which combination is temperature independent or substantially temperature independent. The opposing effects of the two or more types of surfactants (e.g. cationic surfactant and nonionic surfactant) substantially cancel each other to provide a substantially temperature independent surfactant additive.

The invention is also a heat exchanger comprising a first heat exchanging fluid path, and a second heat exchanging fluid path. At least one of the first and second heat exchanging fluid paths further comprises a dedicated degrading device disposed therein. A heat exchanging fluid with a temporarily degradable drag reducing surfactant additive flows in the corresponding heat exchanging fluid path.

The dedicated device is used exclusively for degrading a heat exchanging fluid flowing through the heat exchanger. The most effective dedicated

degrading device imposes a flow disturbance or shear stress uniformly across a cross section of the corresponding heat exchanging fluid path in which the dedicated degrading device is disposed. The dedicated degrading device exposes every surfactant particle flowing in the corresponding heat exchanging fluid path to at least a supercritical stress, which is the amount of stress sufficient to substantially eliminate the drag reducing characteristics of the surfactant solution. The stress imposed by the dedicated degrading device is not significantly higher than the supercritical stress so that the flow energy needed for degradation is minimized. Ideally, the dedicated degrading device is disposed at or near an inlet to the corresponding heat exchanging fluid path.

In the preferred embodiment, the dedicated degrading device comprises a wire mesh disposed across the corresponding heat exchanging fluid path, which also functions as a filter. It is to be expressly understood that many other types of dedicated degrading devices are expressly within the scope of the invention other than mesh obstructions, including specifically devices which do not create an uniform fluid stress, such as valves, pumps, filters, helices, orifices, wires and the like.

Again the invention can be defined as a heat exchanger comprising a first heat exchanging fluid path, and a second heat exchanging fluid path, wherein at least a corresponding one of the first and second heat exchanging fluid paths further comprises a conventional hydraulic component normally found in a circulation system. The hydraulic component is disposed upstream and in

proximity to the corresponding heat exchanging fluid path. A heat exchanging fluid with a temporarily degradable drag reducing surfactant additive is disposed in the corresponding heat exchanging fluid path.

The invention is defined as a method of heat transfer recovery in turbulent flow in a heat exchanger of a drag reducing surfactant fluid characterized by drag reducing fluid properties for degradation and recovery comprising the steps of conditioning the drag reducing fluid properties of the drag reducing surfactant fluid. A degrading device is provided which degrades the fluid with minimum pressure drop. An initial temporary degradation of a circulating fluid is created, and after the fluid is initially degraded one or more smaller disturbances are created downstream to prevent fluid from recovery. A smaller pressure drop than the one used for the initial degradation upstream of heat exchanger can be used to create the smaller disturbances.

In one embodiment the step of conditioning the drag reducing fluid properties of the drag reducing surfactant fluid comprises conditioning the fluid so that it has a faster recovery to achieve asymptotic drag reduction immediately downstream from the heat exchanger.

In another embodiment the step of conditioning the drag reducing fluid properties of the drag reducing surfactant fluid comprises conditioning the fluid so that shear stress generated by pipe stress in the heat exchanging fluid paths of the heat exchanger degrade the fluid.

In still a further embodiment the step of conditioning the drag reducing fluid properties of the drag reducing surfactant fluid comprises conditioning the fluid so that shear stress generated by pipe stress in the heat exchanging fluid paths of the heat exchanger prevents the fluid which has been degraded by the degrading device from recovering.

The invention is still further defined as a fluid characterized by degradation and recovery of its drag reducing properties. The fluid comprises a base component and a surfactant having drag-reducing, fluid degradation, and fluid recovery properties which are substantially independent of temperature when combined with the base component.

The invention is also defined as a method of determining the elimination of drag reducing properties in a fluid including a surfactant comprising the steps of providing a flow of the fluid, providing a degrading device in the flow to eliminate the drag reducing properties of the fluid, creating a pressure drop across the degrading device, and measuring the pressure drop as an indicator of resistance to elimination of the drag reducing properties in the fluid.

The invention now having been briefly summarized, it may now be visualized by reference to the following drawings wherein like elements are referenced by like numerals.

Brief Description of the Drawings

Fig. 1 is a diagram symbolically depicting a heat exchanger.

UNITED STATES RECEIVING OFFICE(RO/US) FEE CODING AND RECORDING SHEET

ADD'L SHEETS

IDENTIFICATION OF THE INTERNATIONAL APPLICATION

INTERNATIONAL APPLICATION NUMBER	INTERNATIONAL FILING DATE
PCT/US99/20220	07 SEP 99

APPLICANT (Name)

PAYMENTS									REFUNDS			
Payment on Filing			Deposit Account		Deposit Account		To Deposit Account		To Deposit Account			
			01	1960								
Deposit Account			DATE: 9/23/99		DATE:		DATE:		DATE:			
CASH/CHECK			CASH/CHECK		CASH/CHECK		BY CHECK		BY CHECK			
150			899	135								
151			566	15								
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800												
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802												
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		Total Paid:	Total Paid: 150		Total Paid:		Total Refunded:		Total Refunded:			
States Included for 892:			892:		892:							
States Included for 893:			893:		893:							

CALCULATED FEE AMOUNT =

AMOUNT OF DIFFERENCE =

09/10/1999 KDUNCAN1 00000036 PCT/US99/20220

01 FC:150 240.00 OP
02 FC:153 450.00 OP
03 FC:800 455.00 OP
04 FC:801 100.00 OP
05 FC:899 840.00 OP
06 FC:899 75.00 OP

10/13/1999 PVOLPE 00000055 011960 PCT/US99/20220

01 FC:899 105.00 CH
02 FC:899 30.00 CH
03 FC:566 15.00 CH

RO/US Authorization	RO/US Authorization	RO/US Authorization	RO/US Authorization	RO/US Authorization

PCT/RO/102(b) (U.S. VERSION)
(Rev. 07-92)

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Fig. 2 is a simplified perspective of a fluid degrading device comprised of a grid or screen insert.

Fig. 3 is a graph showing the drag reduction capacity of a surfactant solution as a function of time after the location of the degrading device exerting the pressure drop needed for the full degradation.

Fig. 4 is a graph of recovery time versus temperature of the surfactant solution for two "opposite" surfactants (e.g. a cationic and nonionic surfactant solution).

The invention and its various embodiments can now be understood by turning to the following detailed description.

Detailed Description Of the Preferred Embodiments

Sufficient mechanical stress imposed on a fluid breaks the micellar structures or micelles themselves, which are the agents affecting turbulence in the flow and causing the drag reduction phenomenon. In this way drag reduction and heat transfer reduction are temporarily turned off. Fig. 1 is a symbolic depiction of a heat exchanger, generally denoted by reference numeral 12. Heat exchanger 12 has a first heat exchanging fluid path 14 in heat exchange relationship with a second heat exchanging fluid path 16,. A first fluid flows through fluid path 14 and absorbs heat from a second fluid flowing through fluid path 16. Fig. 1 shows a counterflow heat exchanger, but any type or design heat exchanger desired could be employed and the symbolic depiction of Fig. 1 is

meant to encompass all types. Heat exchanger 12 may be part of any hydronic system 24 now known or later devised, expressly including any heating or cooling application, or combination of heating and cooling.

In one embodiment, a recirculation loop 24 is provided in one of the fluid paths 16 by which fluid is pumped from outlet 26 by pump 22 to a point at or immediately upstream from inlet 10 to increase the flow rate of fluid through heat exchanger 12 relative to the rest of the hydronic system. By this increased flow rate through the heat exchanger, the heat transfer rate is increased by two mechanisms. First, increased flow velocity increases the shear stress in the heat exchanger pipes and causes degradation of the surfactant solution (change of the fluid properties). Second, increased velocity directly increases heat transfer by increased turbulence (change in the flow). The total effect can provide even a higher heat transfer rate than it was originally, without the use of surfactant additive, at the nominal flow rate through the heat exchanger

The first and/or second fluid can be mechanically degraded at the corresponding inlet 10 to the heat exchanger 12 for each fluid by a degrading device 18, providing the same level of heat transfer as with water for circulating fluid, as long as the fluid remains degraded. Any type of degrading device 18 which applies stress to the fluid to create turbulence to break the micelles or their structure, which device is now known or later devised, may be employed. Fig. 2 shows by way of example only an insert comprised of a grid or mesh screen 20 disposed across the inner diameter of the pipe. A plate provided with a plurality

of apertures or a grating would be included within the explicit range of equivalents of a grid or screen insert, and so would various other devices including wire loops, wall roughnesses, helices, and any other structure capable of creating fluid stress.

Immediately after the excessive stress is removed from the fluid such as occurs when the fluid flows downstream from device 18, the process of rebuilding of micelles and micellar structures begins. The time needed for the total recovery of the fluid drag-reducing ability (hereinafter the "recovery time") should be long enough that the fluid does not show any significant local heat transfer reduction over the residence time of the fluid in heat exchanger 12. An ideal fluid is degraded by degrading device 18 exerting a moderate pressure drop on the flow, but a higher pressure drop than exerted by conventional pipe fittings such as elbows and connectors. The fluid remains totally degraded during its residence time in heat exchanger 12, and recovers quickly as soon as it exits heat exchanger 12.

Fluid properties can be optimized for this purpose, as can the design of degrading device 18 by any one of a number of ways now known or later devised without departing from the scope and spirit of the claimed invention. Different variations on the basic idea are possible, depending on the size and the type of the circulation system in which heat exchanger 12 is included. For example, fluids with a long recovery time may not be provided with additional degradation devices 18 inside heat exchanger 12 beyond an initial degradation device 18, as

may be suited for large heat exchangers, while fluids with a short recovery time are provided with multiple degrading devices 18 inside heat exchanger 12, as may be suited for small heat exchangers.

A special case is a weak fluid degraded by the relatively high or higher than normal wall shear stress in heat exchanger 12. A weak fluid is defined as a fluid with a low critical wall shear stress and/or long recovery time, such as a shear stress close to the level normally encountered in a pipe at nominal fluid velocity. Examples of weak fluids include, but are not limited to lower concentration solutions, and solutions close to their critical temperatures.

Elements of the circulation system like conventional pumps, filters, and flow control valves can be used as degrading devices 18 for degradation if located upstream of heat exchanger 12, thereby eliminating the need for a dedicated degrading device 18, and avoiding the need for an additional pressure drop in the system.

Drag-reducing surfactant solutions reduce friction losses in turbulent pipe flow. However, when the turbulent exchange of momentum is reduced, so is the turbulent exchange of heat. As a result, the heat transfer in the pipes in heat exchanger 12 is reduced too, impairing or prohibiting the use of drag-reducing in systems that involve most types of heat exchangers 12. The conventional techniques used for increasing heat transfer by turbulence enhancement for Newtonian non-drag reducing fluids are effective in increasing heat transfer only up to a factor of 2 to 3 times, and then become prohibitively inefficient, because

of exceedingly high pressure drops in the case where the heat transfer has to be increased by factor of 10, such as in asymptotic drag reduction, which is defined as the maximal drag reduction that can be achieved by drag-reducing additives, typically up to 90% at high enough velocities.

According to the invention the surfactant solution in the heat exchanging fluid or fluids is temporarily degraded preferably for the time the fluids spends in heat exchanger 12, and during that time temporarily loses its properties of drag and heat transfer reduction. The degraded fluid preferably recovers as soon as possible after it exits from heat exchanger 12 to provide desirable drag reduction in the rest of the circulation system.

The most generally applicable means of temporary degradation is by mechanical stress. As discussed above in connection with Fig. 1 the basic and ideal principle is that the fluid is degraded by degrading device 18 at the very inlet 10 to heat exchanger 12, after which it remains completely degraded for the time it spends in heat exchanger 12. The fluid recovers immediately and completely as it exits heat exchanger 12. However, the scope of the invention explicitly includes the disposition of an initial degrading device 18 at any position within in heat exchanger 12. If desired additional degrading devices 18 may be placed at any position downstream from the initial device 18. In the case where multiple degrading devices 18 are used, it is not necessary that they be identical in design or that identical designs be used in both flow fluid paths 14 and 16.

It must be expressly understood that while mechanically induced stress on the fluid is preferred, the stress may be created on the heat exchanging fluid by any mechanism desired including hydrodynamic, ultrasonic, electromagnetic, temperature jumps, or by any other means known or later discovered.

Several concepts are needed for description of the degradation and recovery phenomena utilized in the invention, namely: (1) a state of complete degradation (zero drag reduction and zero heat transfer reduction), (2) the pressure drop on the degrading device (i.e. amount of energy for a unit volumetric flow rate) needed for complete degradation, and (3) the recovery time. The recovery time consists of a dead or hidden recovery time T1 with no signs of recovering drag reduction, and a time T2 of approximately linearly increasing drag reduction until T3 when full drag reduction is recovered as diagrammatically depicted in Fig. 3. Related, but not identical to the pressure drop needed for the full degradation, is the critical shear stress, which is the wall shear stress in the pipe flow above which degradation starts at steady flow conditions. The difference between the two is that degradation by a device 18 is local, implying a very short time of exposure, whereas the critical wall shear stress is defined under steady flow conditions or an unlimited exposure time. For example, with 1,000 ppm of SPE95285 (a non-ionic surfactant by AKZO-Nobel Chemicals), the critical pressure drop on the local degradation device is 0.15 bar, whereas at the critical wall shear stress of 350 Pa over the length of 0.3 m of 15.2mm diameter

pipe is needed for close to complete degradation, or what amounts to a total pressure drop of 0.35 bar over the 0.3m pipe length.

According to the invention the fluid should be designed for optimal heat transfer control. The critical shear stress and pressure drop needed for degradation, the energy needed for degradation, and the recovery time are three relevant parameters in the operation claimed method. They are normally coupled. Stronger fluids, which is to say fluids with higher concentrations of surfactant, typically show a higher drag-reducing ability, a higher pressure drop needed for degradation, and a shorter recovery time. Examples of stronger fluids include, but are not limited to SPE95285 at 1,000 ppm in water at a temperature greater than 20 C or Ethoquad T13 (by AKZO Chemicals) at 1,000 ppm and a temperature lower than 25 C. The mixing of surfactants, the addition of nonsurfactant additives such as alcohols and salts, namely counter ion for cationic surfactants, can change those relationships, allowing better optimization of fluid properties.

For example, the addition of n-decanol to Ethoquad T13 a surfactant manufactured by AKZO-Nobel Chemicals located at Stenungsund, Sweden, decreases fluid drag-reducing ability and increases the recovery time T1 + T2. For example, 1,000 ppm by volume of n-decanol added to a 3,000 ppm solution of SPE95285 surfactant in water at a temperature of 9 C decreases the fluid drag-reducing ability from 70% to 50% under comparable conditions, and increases the recovery time, T1 + T2, from 3 to 10 seconds. If enough surfactant

is added to the solution to recover its drag reducing ability to the level before alcohol was added, the recovery time T1 + T2 of the fully degraded fluid is still about two times higher than for the original solution. Alcohol can thus be used to increase recovery time of the fluid, while maintaining its drag-reducing ability.

All surfactant solutions have their properties strongly dependent on temperature, as it can be readily seen from their phase diagrams (temperature, concentration, phase changes). For example, the recovery time of the SPE95285 surfactant in a cooling system is approximately halved as the temperature changes from 10 to 14 Celsius as depicted in Fig. 4. A similar mechanism operates in the case of heating systems operating in the range of 75 to 100 Celsius or even broader temperature ranges. Most cooling or heating systems work between fixed temperatures (ranging from 5 to 10 Celsius for cooling, for example). This means that optimization of the fluid properties cannot be done for both ends of the temperature range if the recovery time is a function of the temperature, resulting in reduced pumping power savings. The overly long recovery time needed to maintain the full heat transfer capacity of all heat exchangers reduces the total pumping power savings. The cationic surfactant Ethoquad, and apparently most cationic surfactants in general, on the one hand, and nonionic surfactants, on the other, have their phase diagrams as mirror images of each other in terms of temperature as depicted in Fig. 4. This means that for the nonionic surfactant the recovery time increases with reduced temperature. This corresponds to the transition from rod-like to globular

micelles. The same phenomenon causes an increase in the recovery time for the cationic surfactant at increased temperature. Mixing two surfactants with opposite temperature dependence of recovery time (e.g. Ethoquad and SPE95285), makes their degradation and recovery properties almost temperature independent, which contributes greatly to optimized fluid characteristics in terms of adequate heat transfer control. For example, a mixture of 700 ppm by volume of Ethoquad T13 and 700 ppm of SPE95285 surfactant in water results in a mixture in which the recovery time varies no more than 20 % over a temperature range from 8 C to 12 C.

In the most general case, degrading device 18 is placed immediately upstream of heat exchanger 12 for the purpose of temporarily degrading the fluid by imposing a high enough mechanical stress needed for breaking the micellar structures. A certain pressure drop on the degrading device, corresponding to a certain flow work per unit of the flow rate, is needed for degradation. Not all of this pressure drop is actually used for degradation work. A large part of it is dissipated in viscous effects. For example, in the case of a wire mesh degrading device, approximately 5% or less of the energy is used for degradation of the fluid and the remainder is dissipated in viscous effects.

The most effective degrading device 18 is one which can achieve total degradation of the fluid with the minimum pressure drop. The circulation pump must provide this pressure drop which reduces the total pumping power savings. The most effective degrading device 18 is a distributed device, like a wire mesh

20 placed across the pipe cross section as shown in Fig. 2. The wire mesh 20 is about twice as effective as a conventional throttling valve. For example, total degradation is achieved with a pressure drop of 2 psi using mesh 20 as compared to the needed pressure drop of 3.5 psi for a throttling valve. This difference can be explained by the uniformity of the stress imposed on the all fluid particles flowing through mesh 20. Nowhere in the total cross section is the stress higher than needed for the total degradation, and all fluid particles are exposed to the necessary stress. In a conventional valve or other throttling device, if the stress imposed on the fluid in the center of the orifice of the valve is high enough for degradation, the stress close to the orifice edge is much higher than needed for degradation, resulting in unnecessarily high pressure drop on the throttling valve.

Pumps and flow control valves are elements of circulating systems, which dissipate locally large amounts of flow energy. Pumps, with a typical efficiency of 70% dissipate the remaining 30% of the total pumping power through viscous losses. That viscous loss work breaks the micelles. If the pump is appropriately located with respect to heat exchanger 12, such as upstream of the chiller in the cooling system, it takes care of heat transfer recovery in the chiller without the need for a additional degrading device 18 and its associated pressure drop.

Flow control valves normally installed for any cooling or heating coil impose typically 5 psi pressure drop even when open, and can be used to do the degradation job for those types of heat exchangers 12 using any surfactant

solution with long enough recovery time to be useful for this type of application. Altogether, no dedicated degradation device 18, i.e. no additional pressure drop, may in fact be needed for the whole cooling or heating hydronic system using a typical surfactant solution (e.g. 1,500 ppm of SPE95285 at 8 °C), if the flow control valves and pump are appropriately located with respect to heat exchanger 12.

In a small circulating system it may be unacceptable to lose drag-reducing effects in long sections of pipes downstream of heat exchanger 12. This may be the case especially if the fluid shows a linear recovery immediately after degradation without a dead time to prevent any significant recovery of the degraded fluid during its residence in heat exchanger 12. As an alternative, a fluid with a short recovery time may be used, such as a 1,500 ppm of SPE95285 at 20 C, giving a recovery time of less than 5 seconds. However, such a fluid, once degraded at inlet 10 to heat exchanger 12, should be prevented from recovering in heat exchanger 12. This may be achieved by imposing high local stresses in heat exchanger 12 by installing inserts or devices 18 at regular spacing in heat exchanger fluid paths 14 and/or 16. The pressure drop on those inserts or devices 18 can be significantly lower than the pressure drop on the initial degrading device 18 needed for the initial degradation at inlet 10 to heat exchanger 12, while still preventing the recovery of the fluid. For example, the grid spacing of screen 20 may be larger in devices 18 downstream from the initial device 18 at inlet 10 than the grid of the latter . This is another source of energy

savings. After exiting heat exchanger 12, the fluid can then recover very quickly, providing high level of drag reduction immediately downstream of heat exchanger 12. For example, a pressure drop greater than 1.4 psi is needed to degrade fully the fluid initially, whereas additional meshes with only 0.8 psi pressure drop and spaced 1.2 m apart can prevent recovery of the fluid.

Some fluids can have a high level of drag-reducing ability, which is close to asymptotic, and a very short recovery time, but relatively low critical shear stress or wall shear stress in the pipe which degrades the fluid in the steady flow condition at flow velocities only slightly higher than 2 m/s in a ½" pipe. Examples of such fluids are mixtures of SPE95285 and Ethoquad T13 after long-term recirculation. If the flow velocity in a heat exchanger is maintained above this critical velocity, there will be no drag and heat transfer reduction in heat exchanger 12. Of course, the wall shear stress must be kept lower in the rest of the system. Such a fluid may be degraded in conventional pipe fittings, but because of its fast recovery no significant total drag reducing effect is lost. In the case of the fluid above, the recovery occurs within 3 seconds.

A degrading device may be used at the inlet 10 to heat exchanger 12 when using a weak fluid, such as that above. However, a higher shear stress in heat exchanger fluid paths 14 and 16 as compared to the stress in the rest of the system can then be used to prevent fluid from recovering in heat exchanger 12, thereby providing the benefits of a short recovery time, as explained above.

Many alterations and modifications may be made by those having ordinary skill in the art without departing from the spirit and scope of the invention. While many of the specific above examples are given in terms of cooling systems, it must be emphasized that the invention applies with equal applicability to heating systems and applications. Therefore, it must be understood that the illustrated embodiment has been set forth only for the purposes of example and that it should not be taken as limiting the invention as defined by the following claims.

The words used in this specification to describe the invention and its various embodiments are to be understood not only in the sense of their commonly defined meanings, but to include by special definition in this specification structure, material or acts beyond the scope of the commonly defined meanings. Thus if an element can be understood in the context of this specification as including more than one meaning, then its use in a claim must be understood as being generic to all possible meanings supported by the specification and by the word itself.

The definitions of the words or elements of the following claims are, therefore, defined in this specification to include not only the combination of elements which are literally set forth, but all equivalent structure, material or acts for performing substantially the same function in substantially the same way to obtain substantially the same result. In this sense it is therefore contemplated that an equivalent substitution of two or more elements may be made for any one of the elements in the claims below or that a single element may be substituted

for two or more elements in a claim.

Insubstantial changes from the claimed subject matter as viewed by a person with ordinary skill in the art, now known or later devised, are expressly contemplated as being equivalently within the scope of the claims. Therefore, obvious substitutions now or later known to one with ordinary skill in the art are defined to be within the scope of the defined elements.

The claims are thus to be understood to include what is specifically illustrated and described above, what is conceptionally equivalent, what can be obviously substituted and also what essentially incorporates the essential idea of the invention.

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We claim.

1. An improvement in a hydronic system including a heat exchanger when using a drag-reducing surfactant solution as a thermal distribution fluid comprising:

a surfactant solution flowing through said heat exchanger, which surfactant reduces fluid drag within said hydronic system, but not necessarily within said heat exchanger, said surfactant solution characterized by an optimized recovery time as defined by ability of said surfactant solution to rebuild molecular or micellar structures after disruption of said molecular or micellar structures; and

a fluid degradation device to create temporary fluid degradation in said heat exchanger to break or disrupt said molecular or micellar structures in said surfactant solution by high local shear stresses so that heat transfer rate of said surfactant solution is increased in the heat exchanger for a predetermined distance or time downstream from said degradation device, during which recovery time said molecular or micellar structures are being rebuilt, subsequent to which full drag and heat transfer reductions are again achieved,

whereby heat exchanger efficiency is recovered to an original level obtained without surfactant to achieve overall energy savings in said hydronic system.

2. An improvement in a method of heat exchange in a hydronic system comprising:

providing a surfactant solution as a heat exchanging fluid in a heat exchanger included within said hydronic system, which surfactant solution reduces fluid drag within said hydronic system, said surfactant solution characterized by a predetermined recovery time as defined by ability of said surfactant solution to rebuild molecular or micellar structures after disruption of said molecular or micellar structures; and disturbing flow in said heat exchanger to break or disrupt said molecular or micellar structures in said surfactant solution by high local shear stresses so that heat transfer rate of said surfactant solution is returned to a level approximating heat transfer rate of said heat exchanging fluid without said surfactant added for a predetermined distance downstream from said disturbance during said recovery time during which said molecular or micellar structures are being rebuilt.

3. A method of heat transfer recovery in turbulent flow of drag reducing surfactant solutions comprising

providing a degrading device which degrades the fluid with minimum pressure drop;

creating temporary degradation of a circulating fluid; and

conditioning of the drag reducing fluid properties relevant for degradation and recovery.

4. A fluid having optimized properties of degradation and recovery comprising:

a thermal transport fluid; and

a surfactant additive capable of withstanding stress in all pipes and fittings of a circulation system and providing asymptotic drag reduction in straight pipes, and some drag reduction in fittings, whereas in a heat exchanger in which said fluid is degraded by a degrading device, the drag and heat transfer reductions are temporarily substantially eliminated, said fluid remaining substantially degraded during its residence in said heat exchanger after which recovery occurs quickly after said fluid exits from heat exchanger.

5. The fluid of claim 4 where said fluid and surfactant in combination are characterized by a drag reduction recovery having a long dead time at substantially reduced drag reduction and a fast recovery to a substantially undegraded drag reduction level.

6. A fluid having optimized properties of degradation and recovery comprising:

a thermal transport fluid; and

a surfactant additive having, when added to said thermal transport fluid, a substantial independence of drag-reducing ability, degradation, and recovery properties as a function of temperature.

7. The fluid of claim 6 wherein said surfactant additive comprises a mixture of surfactants with opposing effects of temperature on drag-reducing ability, degradation, and recovery time.

8. The fluid of claim 7 where said mixture of surfactants comprises a cationic surfactant and a nonionic surfactant in which opposing effects of said cationic surfactant and nonionic surfactant substantially cancel each other to provide a substantially temperature independent surfactant additive.

9. A heat exchanger comprising:

a first heat exchanging fluid path;

a second heat exchanging fluid path, wherein at least one of said first and second heat exchanging fluid paths further comprises a dedicated degrading device disposed therein; and

a heat exchanging fluid with a temporarily degradable drag reducing surfactant additive disposed in said corresponding heat exchanging fluid path.

10. The heat exchanger of claim 9 wherein said dedicated device is used exclusively for degrading a heat exchanging fluid flowing through said heat exchanger.

11. The heat exchanger of claim 9 wherein said dedicated degrading device imposes a flow disturbance or shear stress uniformly across a cross section of said corresponding heat exchanging fluid path in which said dedicated degrading device is disposed.

12. The heat exchanger of claim 11 wherein said dedicated degrading device exposes every surfactant particle flowing in said corresponding heat exchanging fluid path to at least a supercritical stress.

13. The heat exchanger of claim 12 wherein said stress imposed by said dedicated degrading device is not significantly higher than said supercritical stress so that the flow energy needed for degradation is minimized.

14. The heat exchanger of claim 9 wherein said dedicated degrading device is disposed at or near an inlet to said corresponding heat exchanging fluid path.

15. The heat exchanger of claim 9 wherein said dedicated degrading device comprises a wire mesh disposed across said corresponding heat exchanging fluid path.

16. The heat exchanger of claim 15 wherein said wire mesh also functions as a filter.

17. A heat exchanger comprising:

a first heat exchanging fluid path;

a second heat exchanging fluid path, wherein at least a corresponding one of said first and second heat exchanging fluid paths further comprises a conventional hydraulic component normally found in a circulation system, which hydraulic component is disposed upstream and in proximity to said corresponding heat exchanging fluid path; and

a heat exchanging fluid with a temporarily degradable drag reducing surfactant additive disposed in said corresponding heat exchanging fluid path.

18. A method of heat transfer recovery in turbulent flow in a heat exchanger by means of a drag reducing surfactant fluid characterized by degradation and recovery of drag reducing fluid properties comprising:

conditioning said drag reducing fluid properties of said drag reducing surfactant fluid;

providing a degrading device which degrades the fluid with minimum pressure drop;

creating an initial temporary degradation of a circulating fluid in a flow of said fluid in said heat exchanger; and

after said fluid is initially degraded, creating additional disturbances in said flow to prevent recovery of the fluid.

19. The method of claim 18 where a smaller pressure drop than the one used for said initial degradation upstream of heat exchanger is used to create said smaller disturbance.

20. The method of claim 19 where conditioning said drag reducing fluid properties of said drag reducing surfactant fluid with a faster recovery to achieve asymptotic drag reduction immediately downstream from said heat exchanger.

21. The method of claim 19 where conditioning said drag reducing fluid properties of said drag reducing surfactant fluid by pipe stress to use shear

stress generated by said heat exchanging fluid paths of said heat exchanger to degrade said fluid.

22. The method of claim 9 where conditioning said drag reducing fluid properties of said drag reducing surfactant fluid by pipe stress to use shear stress generated by said heat exchanging fluid paths of said heat exchanger to prevent said fluid degraded by said degrading device from recovering.

23. The improvement of claim 2 further comprising maintaining flow rate of said heat exchanging fluid in said hydronic system, while flow rate of said heat exchanging fluid in said heat exchanger is increased in the heat exchanger through the addition of a secondary pump located in parallel with the heat exchanger and connected to the inlet and outlet of the heat exchanger.

24. A fluid comprising:

a base component; and

a surfactant having drag-reducing, fluid degradation, and fluid recovery properties which are substantially independent of temperature when combined with said base component.

25. A method of characterizing degradability of a fluid and degradation work imposed on a fluid comprising:

providing a flow of said fluid;

providing a degrading device in said flow to degrade said drag reducing properties of said fluid;

creating a pressure drop across said degrading device; and

measuring said pressure drop as an indicator of resistance to degradation of said drag reducing properties in said fluid, as well as an indicator of the degradation work imposed on the fluid.

26. A method of managing degradability of a fluid and degradation work imposed on a fluid comprising:

providing a flow of said fluid;

providing a degrading device in said flow to degrade said drag reducing properties of said fluid;

creating a pressure drop across said degrading device; and

providing a predetermined amount of time after degradation of said drag reducing properties of said fluid to allow recovery of said fluid without additional degradation work being performed, said predetermined amount of time being independent of velocity of said fluid.

27. A method of increasing heat transfer in a hydronic system having a heat exchanger over nominal design limits, said heat exchanger having a heat transport fluid therein which is characterized by a heat transfer rate, comprising:

adding a surfactant to said heat transport fluid to reduce drag in said hydronic system;

providing a flow of said heat transport fluid and said surfactant through said heat exchanger at an increased rate over said nominal design limits; and

providing a degrading device in said flow in said heat exchanger to degrade said drag reducing properties of said surfactant in order to increase said heat transfer rate of said heat transport fluid in said heat exchanger.

METHODS TO CONTROL HEAT TRANSFER IN FLUIDS CONTAINING DRAG-REDUCING ADDITIVES

Abstract of the Disclosure

Heat transfer can be enhanced or recovered in a heat exchanger through which drag-reducing surfactant additives are flowing with fluid degradation elements inserted therein to increase heat exchange efficiency to bring the heat transfer capacity back to or close what would have been realized in the same heat exchanger operating with water without the drag reducing additive, notwithstanding the fact that the heat transfer would otherwise have been reduced by use of the drag reducing surfactant additives. Instead of affecting the flow as in common turbulators used for Newtonian fluids, the method relies on changing the actual fluid and its properties. The drag-reducing and the accompanying heat transfer-reducing ability of the fluid are eliminated temporarily through the temporary degradation of its molecular superstructure over the residence time of the fluid in the heat exchanger. This degradation is achieved by an intentional mechanical stress imposed on the fluid. The invention comprises two main parts: (1) the design of a fluid with optimal properties for intentional degradation; and (2) the use of efficient devices for the degradation.

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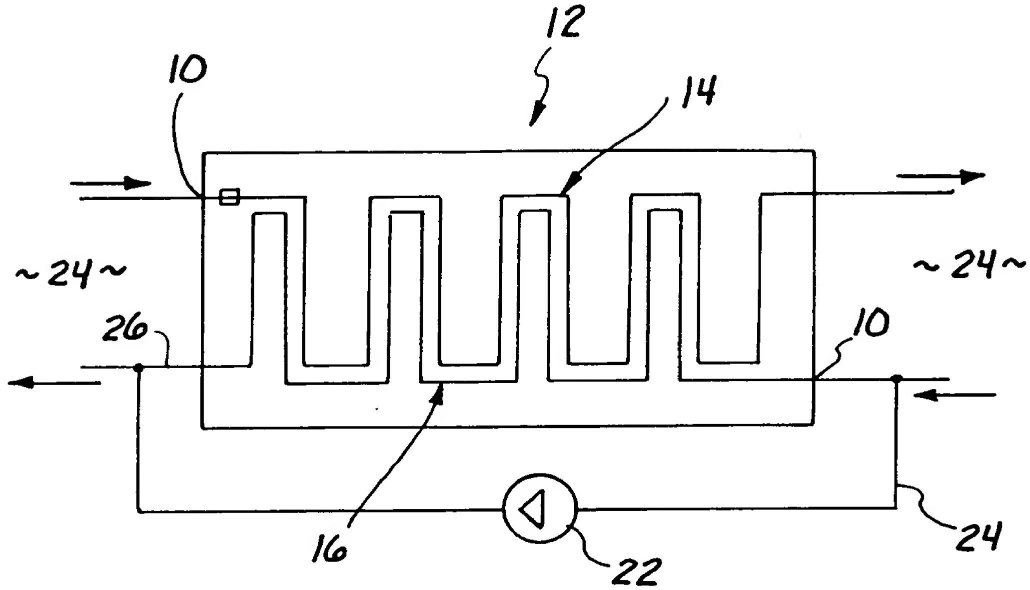

Fig. 1

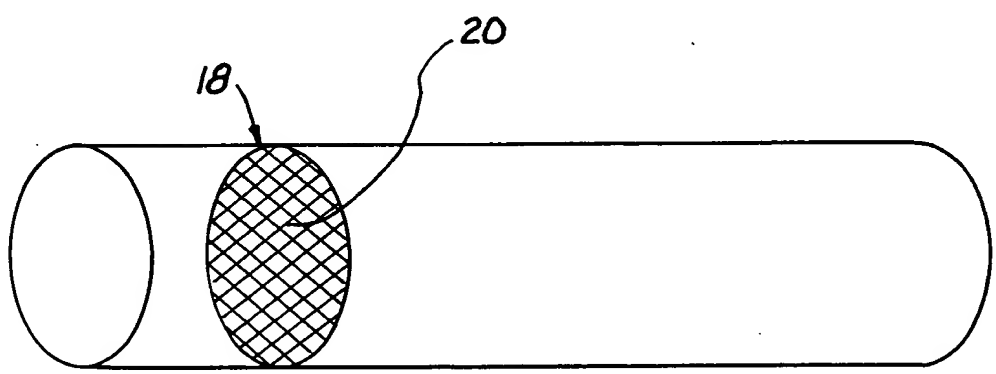

Fig. 2

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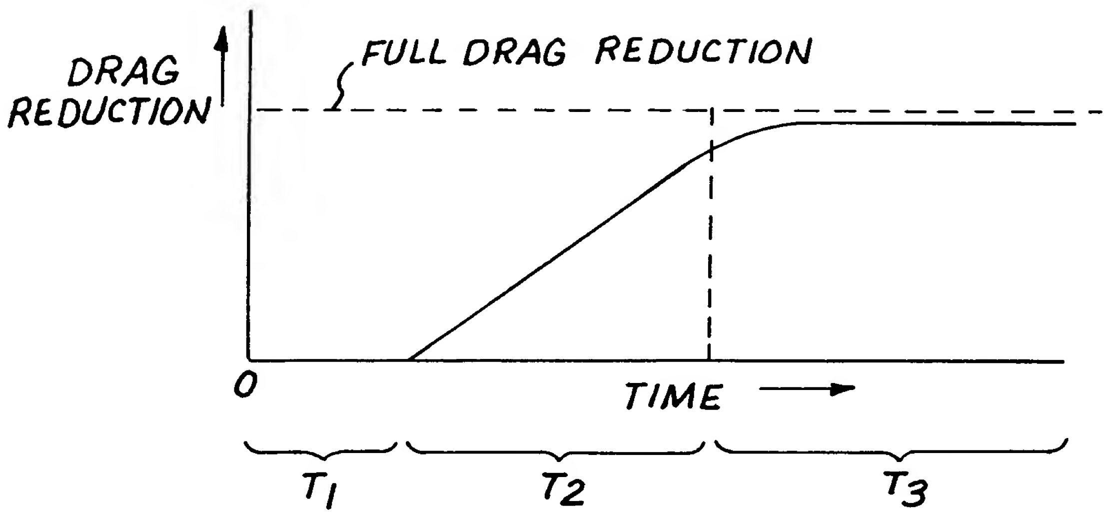

Fig. 3

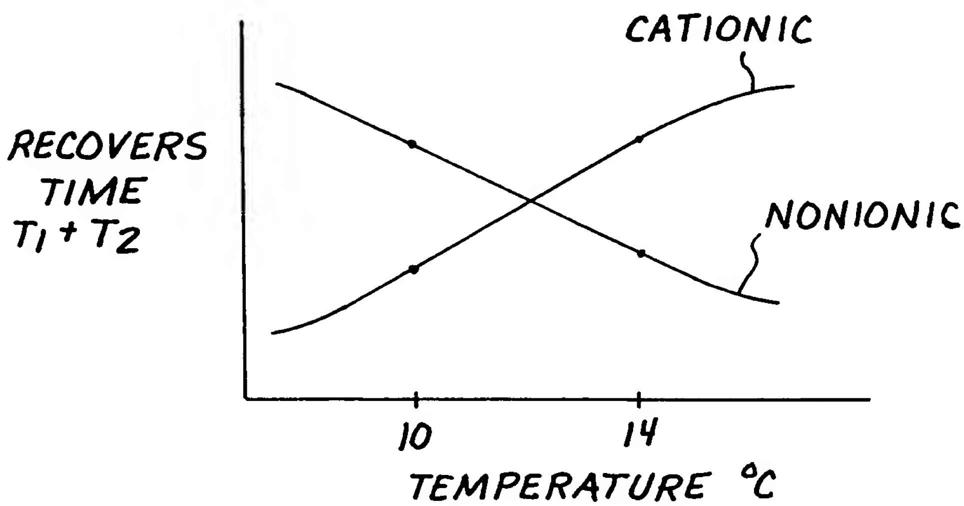

Fig. 4

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

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NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

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Date of mailing (day/month/year) 17 May 2000 (17.05.00)	
International application No. PCT/US99/20220	**Applicant's or agent's file reference** P368b-PCT
International filing date (day/month/year) 02 September 1999 (02.09.99)	**Priority date** (day/month/year) 03 September 1998 (03.09.98)
Applicant GASLJEVIC, Kazimir et al	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   30 March 2000 (30.03.00)

   [ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was
   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer C. Villet Telephone No.: (41-22) 338.83.38

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/20220

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :F24H 3/00; C10M 105/08; C09K 5/00
US CL :165/47; 252/34, 71
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 165/47; 252/34, 71

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,143,635 A (YOUNG et al) 01 September 1992, see entire document.	1-27
X	US 4,534,875 A (ROSE) 13 August 1985, see entire document.	1-27

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 OCTOBER 1999	18 NOV 1999

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